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Original Article

Relationships between the quantitative ultrasound measurement of the of lower limb bones, muscular performance and anaerobic capacities in Malay university students

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Abstract
Problem statement: Data on bone health status, muscular peak torque (an indicator of muscular strength) and power is still lacking in non-active young Malays. Moreover, no study has been undertaken to investigate the association between bone health and anaerobic capacity in the Malay population. Hence, the present study was designed to address the paucity of this information. **Approach:** Young, healthy Malay females (n=33) and males (n=33) university students aged 18-25 years old were recruited for this study. The quantitative ultrasound measurements of bone speed of sound (SOS) in the legs were measured using a bone sonometer. Muscular peak torque of knee extension and flexion at $60^0.s^{-1}$ and $180^0.s^{-1}$ were measured using a BIODEX isokinetic dynamometer. Anaerobic capacities of the participants were determined via the Wingate anaerobic test. **Purpose:** To investigate the relationships of lower limbs' quantitative ultrasound measurement of the bones with muscular peak torque and anaerobic capacities in Malay university students. **Results:** Correlation coefficient (r) between non-dominant tibial SOS and muscular peak torque at $60^0.s^{-1}$ and $180^0.s^{-1}$ in female participants was 0.448 (p=0.009) and 0.388 (p=0.026) respectively. In males, moderate correlation was found between non-dominant tibial SOS and muscular peak torque at $180^0.s^{-1}$ knee flexion (r=0.419, p=0.015). **Conclusions:** There were moderate correlations ($p<0.05$) between muscular peak torque, mean power and peak power in the male participants. Nevertheless, no significant correlations were observed between tibial SOS and anaerobic capacities of mean power and peak power in both females and males. There were moderate relationships between quantitative ultrasound measurement of the bones with muscular strength, but not with anaerobic capacities in university students.
Keywords: Bone speed of sound, muscular strength, anaerobic power, Malays

Introduction

Bone health is influenced by age, gender, race, nutrition, life style, exercise, and hormonal factors as well as muscle strength (Hochberg, 2007; Blain et al., 2001; Taaffe et al., 2001; Burr, 1997). Regarding association between muscular strength and bone health, Ahedi *et al.* (2014) investigated the relationship between muscle strength and bone mineral density (BMD) of the hip and spine in 321 Tasmanian older adults and reported that hip BMD was positively related to the muscular strength, and the authors concluded that higher muscular strength may maintain bone health and prevent bone fragility and fractures. Similarly, Lee *et al.* (2014) also reported that muscular strength is associated with BMD of hip in healthy elderly women. Regarding the associations between bone mineral density and muscle anaerobic capacities, such as explosive power, Nasri *et al.* (2013) found that hand grip strength and explosive leg power were significantly correlated with BMD of both spine and legs among fifty adolescent combat sports athletes aged 17 years.

It is well known that osteoporosis is a systematic bone disease characterized by loss of bone contents and progressive deterioration of microarchitecture of the bone, which would lead to bone fragility and fractures eventually (Wass & Owen, 2014; Tung & Iqbal, 2007). In 1994, the World Health Organization recommended that dual energy X-ray absorptiometry (DXA) is the gold standard method for the diagnosis of osteoporosis and

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measurement of bone mineral density (BMD) (WHO, 1994). Nevertheless, many other techniques are available to evaluate bone health in recent years (WHO, 2004). One of the popular techniques is quantitative ultrasound (QUS), which uses sound waves to diagnose osteoporosis and assess bone health status of an individual (Miura, Saavedra, and Yamamoto, 2008; Mészáros et al., 2007; Baroncelli, 2008; Mimura et al., 2008). Today, more and more researchers use devices based on quantitative ultrasound to evaluate osteoporosis due to its portability, proper practicality and cheaper cost for the public to access. Ng and Sundram (1998) reported that quantitative ultrasound provides bone speed of sound (SOS) results which can contribute additional information on bone contents and microarchitectures as well as BMD. The speed of sound of bone, which is an alternative to DXA for osteoporosis screening, can be measured by quantitative ultrasound through bone at the phalanx, radius, tibia and metatarsal (Njeh et al., 2001; Giangregorio & Webber, 2004).

To date, data on bone health status, muscular peak torque (an indicator of muscular strength) and power is still lacking in non-active young Malays. Moreover, no study has been undertaken to investigate the association between bone health and anaerobic capacity in the Malay population. Hence, the present study was designed to address the paucity of this information. We hypothesized that there are positive relationships between quantitative ultrasound measurement of the bone of the lower limbs, muscular peak torque, power and anaerobic capacity in Malay females and males. The present study aimed to investigate the association between bone health status, muscular performance and anaerobic capacities among Malay females and males university students. It is hoped that results of the present study can be used to guide researchers for the measurements and assessments of bone health status and muscular strength effectively and efficiently in the field of exercise and sports science.

Materials & Methods

Study participants

Sixty-six healthy non-physically active female and male Malays volunteered for the study (females, n=33; males, n=33). Potential participants were recruited by advertisement within Universiti Sains Malaysia. The potential subjects were required to contact the investigators if they were interested to participate in the study. The participants were between 18 to 25 years old and exercised less than 2 times per week prior to the study period. The participants were Malays who resided in Malaysia with at least three generations residing in peninsula Malaysia and were individuals with family history without any admixture or inter-marriage. Detailed questionnaires concerning medical condition, family history, lifestyle and exercise habits were answered by the participants, and consent form was obtained from each participant before the commencement of the study. The study was approved by the Human Research Ethics Committee of Universiti Sains Malaysia. The sample size in the present study was determined according to Jayapalan *et al.* (2008) by considering a study power of 80%, 0.05 probability of type I error, and a dropout rate of 10%.

Measurement of anthropometric parameters

Participants' anthropometric parameters, i.e. body weight, height, percentage of body fat (%BF), resting heart rate and blood pressure were measured in this study. All participants' body weight and height were measured using a scale and stadiometer (Seca 220, Hamburg, Germany). Body composition phenotype i.e. percent body fat (%BF) was measured using a "foot-to-foot" body composition analyzer (Tanita TBF-410, Japan). An automatic upper arm blood pressure monitor (TM-2540, San Jose, USA) was used to measure participants' resting heart rate and blood pressure. The records of measurements were done in triplicates for accuracy and the average of three measurements was used as the final result.

Measurement of Wingate Anaerobic Capacities

In Wingate anaerobic capacity test, participants performed a 30-s cycling on a cycle ergometer (H-300-R Lode, Groningen, Holland) at maximal propelling speed (Bar-Or, 1987). Participant was seated comfortably on a cycle ergometer with friction-loaded flywheel. After completing a 1 minute warm-up at 60 rpm using low aerobic workload (50 Watt), participants were instructed to increase their pedaling frequency to as fast as possible. At the signal "Go", the participant began to pedal maximally. When the participant's cadence reached their highest rpm at no resistance, the electromagnet released the weight pan and the 30-second test began. Verbal encouragement was provided to motivate the participant to pedal at a maximal effort throughout the duration of the test. Mean power and peak power throughout the 30-second test were recorded. Following the completion of the Wingate test, participants cycled at a low aerobic workload (25-100 Watt) for 2-5 minutes as an active recovery (Bar-Or, 1987; Lericollais, 2009).

Muscular knee peak torque (strength) measurement

In this study, isokinetic knee extension and flexion peak torque were assessed at 2 angular velocities of movement using BIODEX dynamometer (VAC system 3 PRO, New York, USA) with a rest period of 10 s between the trials: $60^0.s^{-1}$ and $180^0.s^{-1}$ (Pincivero, Lephart and Karunakara, 1997). Testing at each velocity consisted of 5 sub-maximal followed by 2-3 maximal repetitions for warm-up purposes. Ten maximal repetitions were performed at $180^0.s^{-1}$, and five maximal repetitions were then performed at $60^0.s^{-1}$. During the testing procedure, each participant was given verbal encouragement as well as visual feedback from an investigator in an attempt to achieve a maximal effort level (Hald & Bottjen, 1987)

Bone speed of sound (SOS) measurement

The quantitative ultrasound measurements of bone speed of sound (SOS, $m.s^{-1}$) were measured using a bone sonometer (Sunlight MiniOmni^{TM}, Petah Tikva, Israel) (Steinschneider, 2003). Ultrasound was emitted by the generating transducers and transmitted along the bone. The mid-shaft tibias of both lower limbs were the measurement sites in this study. Before the measurements, system quality verification was done. The region of measurement for the tibia of the dominant and non-dominant leg was defined as the area halfway between the plantar surface of the heel and the proximal edge of the knee. Prior to the measurements, system quality verification of the bone sonometer was carried out. The scan site was then marked using a skin marker. Scanning process began by moving a measuring probe from the lateral side to the medial side of the measured limbs. The result of bone speed of sound was then recorded.

Statistical analysis

Statistical analysis was performed by using SPSS version 20. Independent t tests were used for comparisons of physical characteristics, bone speed of sound, Wingate anaerobic capacities of mean power and peak power and muscular peak torque between females and males. Pearson correlations were performed to explore the relationships between the measured parameters. All data were presented as mean ± standard deviation, unless otherwise stated. A "p" value of less than 0.05 was considered significant.

Results

Thirty-three young Malay female and 33 Malay male students from Universiti Sains Malaysia completed the study. The mean age of the participants was 21.5 ± 1.1 years old in females, and 20.5 ± 1.6 years old in males. Physical characteristics of all participants are shown in Table 1. There were statistically significant higher values of body weight (p=0.001), body height (p<0.001), basal metabolic rate (p<0.001), diastolic blood pressure (p=0.003) and systolic blood pressure (p<0.001) in males compared to females. However, statistically significant lower percent body fat (p=0.001) and resting heart rate (p=0.002) were observed in males compared to females in the present study.

Table 1.Physical characteristics of participants

	Malay females (n=33)	Malay males (n=33)	*p* value
Body weight (kg)	52.7 ± 11.3	**64.2 ± 14.0****	**0.001**
Body height (cm)	154.1 ± 6.5	**168.1 ± 5.9****	**<0.001**
%BF (%)	28.9 ± 8.0	**21.9 ± 7.6****	**0.001**
BMR ($kJ.day^{-1}$)	4964.5 ± 556.8	**6337.7 ± 602.8****	**<0.001**
RHR ($beats.min^{-1}$)	86.6 ± 10.1	**76.6 ± 14.4****	**0.002**
DBP (mmHg	65.7 ± 8.1	**71.8 ± 8.2****	**0.003**
SBP (mmHg	108.2 ± 10.4	**122.4 ± 13.0****	**<0.001**

Values are expressed as means ± SD. Bold numbers* indicates statistically significant. *P*<0.05 was considered as statistically significant.

Abbreviations: %BF: percent body fat; BMR: basal metabolic rate; RHR: resting heart rate; DBP: diastolic blood pressure; SBP: systolic blood pressure.

	Malay females (n=33)	Malay males (n=33)	*P* value
Dominant tibia SOS ($m{\cdot}s^{-1}$)	3997.9 ± 138.0	**3897.0 ± 127.7****	**0.003**
Non-dominant tibia SOS ($m{\cdot}s^{-1}$)	3972.5 ± 145.2	3933.1 ± 130.8	0.251
Mean power (Watt)	190.3 ± 55.8	**422.7 ± 68.8****	**<0.001**
Peak power (Watt)	350.3 ± 32.1	**563.0 ± 116.0****	**<0.001**
Dominant knee extension peak torque ($60^0.S^{-1}$) (Nm)	89.0 ± 26.1	**157.6 ± 33.6****	**<0.001**
Dominant knee extension peak torque ($180^0.S^{-1}$) (Nm)	55.8 ±19.9	**113.4 ±29.0****	**<0.001**
Dominant knee flexion peak torque ($60^0.S^{-1}$)(Nm)	37.9 ±12.4	**69.0 ±22.5****	**<0.001**
Dominant knee flexion peak torque ($180^0.S^{-1}$) (Nm)	31.3 ±11.7	**63.0 ±17.28****	**<0.001**
Non-dominant knee extension peak torque ($60^0.S^{-1}$) (Nm)	88.5 ± 26.6	**146.1 ± 32.4****	**<0.001**
Non-dominant knee extension peak torque ($180^0.S^{-1}$) (Nm)	58.6 ± 19.2	**107.3 ± 25.4****	**<0.001**
Non-dominant knee flexion peak torque ($60^0.S^{-1}$) (Nm)	42.6 ± 39.4	**64.4 ± 20.0****	**0.007**
Non-dominant knee flexion peak torque ($180^0.S^{-1}$) (Nm)	32.8 ± 14.4	**61.2 ± 14.9****	**<0.001**

Values are expressed as means ± SD. Bold numbers* indicates statistically significant. *P*<0.05 was considered as statistically significant.
Abbreviations: SOS: quantitative ultrasound measurements of bone speed of sound.

Table 2.Quantitative ultrasound measurements of bone speed of sound (SOS) of the dominant and non-dominant lower limbs, Wingate anaerobic capacities of mean power and peak power, and muscular peak torque of the participants (Mean ± SD)

Table 2 exhibited the mean value of the quantitative ultrasound measurement of the bones of the dominant and non-dominant lower limbs, Wingate anaerobic capacities and muscular peak torque in females and males. There was a statistically significant lower value of dominant tibia SOS in males compared to females (p=0.003). However, no statistically significant difference was observed in non-dominant tibia SOS among females and males (p=0.251). Mean power, peak power, dominant and non-dominant knee extension and flexion peak torque at $60^0.s^{-1}$ and $180^0.s^{-1}$ were also significantly higher in the males compared to females (p<0.01).

The correlation matrix between tibial bone measurements of speed of sound, anaerobic capacities of mean power and peak power, and muscular peak torque in females and males are illustrated in Table 3 and Table 4 respectively. It was found that the moderate positive correlation between non-dominant tibial SOS and muscular extension peak torque at $60^0.s^{-1}$ and $180^0.s^{-1}$ in females was 0.448 (p=0.009) and 0.388 (p=0.026) respectively (Table 3). No statistically significant correlations were observed between dominant and non-dominant tibial SOS, mean power and peak power in females (Table 3). In males, the correlation coefficient (r) between non-dominant tibial SOS and muscular peak torque at $180^0.s^{-1}$ knee flexion in males was 0.419 (p=0.015) (Table 4). There were moderate positive correlations (p=0.000 to p=0.045) between muscular peak torque, mean power and peak power in males (Table 4). However, there was no statistical significant correlation between dominant and non-dominant tibial SOS, mean power and peak power in males.

Table 3.Correlation matrix between tibia bone measurements of speed of sound, anaerobic capacities of mean power and peak power and muscular peak torque in females

					Dominant knee extension		Dominant knee flexion		Non-Dominant knee extension		Non-Dominant knee flexion	
	Dominant Tibia SOS	**Non-dominant Tibia SOS**	**Mean power**	**Peak power**	**Peak torque (60^0.S^{-1})**	**Peak torque (180^0.S^{-1})**	**Peak torque (60^0.S^{-1})**	**Peak torque (180^0.S^{-1})**	**Peak torque (60^0.S^{-1})**	**Peak torque (180^0.S^{-1})**	**Peak torque (60^0.S^{-1})**	**Peak torque (180^0.S^{-1})**
Dominant Tibia SOS	_	_	r=0.027 p=0.883	r=0.231 p=0.196	r=0.315 p=0.074	r=0.317 p=0.072	r=0.360 p=0.040	r=0.323 p=0.067	_	_	_	_
Non-dominant Tibia SOS	_	_	r=0.285 p=0.108	r=0.226 p=0.206	_	_	_	_	**r=0.448 p=0.009**	**r=0.388 p=0.026**	r=0.097 p=0.592	r=0.095 p=0.617
Mean power	r=0.027 p=0.883	r=0.285 p=0.108	_	r=0.058 p=0.746	r=0.063 p=0.726	r=0.164 p=0.722	r=0.064 p=0.722	r=0.164 p=0.362	r=0.002 p=0.990	r=0.097 p=0.590	r=0.112 p=0.534	r=0.117 p=0.518
Peak power	r=0.231 p=0.196	r=0.226 p=0.206	r=0.058 p=0.746	_	r=0.176 p=0.328	r=0.042 p=0.816	r=0.042 p=0.816	r=0.118 p=0.512	r=0.197 p=0.271	r=0.004 p=0.983	r=0.036 p=0.840	r=0.364 p=0.038
Dominant knee extension peak torque (60^0.S^{-1})	r=0.315 p=0.074	_	r=0.063 p=0.726	r=0.176 p=0.328	_	r=0.856 p=0.000	r=0.865 p=0.000	r=0.784 p=0.000	r=0.928 p=0.000	r=0.867 p=0.000	r=0.091 p=0.613	r=0.804 p=0.000
Dominant knee extension peak torque (180^0.S^{-1})	r=0.317 p=0.072	_	r=0.164 p=0.722	r=0.042 p=0.816	r=0.856 p=0.000	_	r=0.725 p=0.000	r=0.724 p=0.000	r=0.757 p=0.000	r=0.878 p=0.000	r=0.102 p=0.572	r=0.677 p=0.000
Dominant knee flexion peak torque (60^0.S^{-1})	r=0.360 p=0.040	_	r=0.064 p=0.722	r=0.042 p=0.816	r=0.865 p=0.000	r=0.725 p=0.000	_	r=0.811 p=0.000	r=0.839 p=0.000	r=0.811 p=0.000	r=0.044 p=0.806	r=0.808 p=0.000
Dominant knee flexion peak torque (180^0.S^{-1})	r=0.323 p=0.067	_	r=0.164 p=0.362	r=0.118 p=0.512	r=0.784 p=0.000	r=0.724 p=0.000	r=0.811 p=0.000	_	r=0.724 p=0.000	r=0.861 p=0.000	r=0.209 p=0.244	r=0.843 p=0.000
Non-dominant knee extension peak torque (60^0.S^{-1})	_	**r=0.448 p=0.009**	r=0.002 p=0.990	r=0.197 p=0.271	r=0.928 p=0.000	r=0.757 p=0.000	r=0.839 p=0.000	r=0.724 p=0.000	_	r=0.829 p=0.000	r=0.093 p=0.607	r=0.867 p=0.000
Non-dominant knee extension peak torque (180^0.S^{-1})	_	**r=0.388 p=0.026**	r=0.097 p=0.590	r=0.004 p=0.983	r=0.867 p=0.000	r=0.878 p=0.000	r=0.811 p=0.000	r=0.861 p=0.000	r=0.829 p=0.000	_	r=0.150 p=0.405	r=0.814 p=0.000
Non-dominant knee flexion peak torque (60^0.S^{-1})	_	r=0.097 p=0.592	r=0.112 p=0.534	r=0.036 p=0.840	r=0.091 p=0.613	r=0.102 p=0.572	r=0.044 p=0.806	r=0.209 p=0.244	r=0.093 p=0.607	r=0.150 p=0.405	_	r=0.347 p=0.480
Non-dominant knee flexion Peak torque (180^0.S^{-1})	_	r=0.095 p=0.617	r=0.117 p=0.518	r=0.364 p=0.038	r=0.804 p=0.000	r=0.677 p=0.000	r=0.808 p=0.000	r=0.843 p=0.000	r=0.867 p=0.000	r=0.814 p=0.000	r=0.347 p=0.480	_

Person correlations were performed to explore the relationships between measured parameters. Bold numbers* indicates statistically significant. p<0.05 was considered as statistically significant.

Abbreviations: SOS: quantitative ultrasound measurements of bone speed of sound.

Table 4.Correlation matrix between tibia bone measurements of speed of sound, Wingate anaerobic capacities of mean power and peak power and muscular peak torque in males

					Dominant knee extension		Dominant knee flexion		Non-Dominant knee extension		Non-Dominant knee flexion	
	Dominan Tibia SOS	**Non-dominant Tibia SOS**	**Mean power**	**Peak power**	**Peak torque $(60^0.S^{-1})$**	**Peak torque $(180^0.S^{-1})$**	**Peak torque $(60^0.S^{-1})$**	**Peak torque $(180^0.S^{-1})$**	**Peak torque $(60^0.S^{-1})$**	**Peak torque $(180^0.S^{-1})$**	**Peak torque $(60^0.S^{-1})$**	**Peak torque $(180^0.S^{-1})$**
Dominant Tibia SOS	_	_	r=0.200 p=0.265	r=0.294 p=0.097	r=0.007 p=0.971	r=0.032 p=0.861	r=0.080 p=0.659	r=0.080 p=0.657	_	_	_	_
Non-dominant Tibia SOS	_	_	r=0.253 p=0.156	r=0.186 p=0.300	_	_	_	_	r=0.069 p=0.704	r=0.015 p=0.934	r=0.263 p=0.139	**r=0.419** **p=0.015**
Mean power	r=0.200 p=0.265	r=0.253 p=0.156	_	r=0.793 p=0.000	**r=0.388** **p=0.025**	**r=0.465** **p=0.006**	**r=0.403** **p=0.020**	**r=0.449** **p=0.009**	r=0.205 p=0.252	**r=0.351** **p=0.045**	r=0.256 p=0.150	r=0.247 p=0.165
Peak power	r=0.294 p=0.097	r=0.186 p=0.300	r=0.793 p=0.000	_	**r=0.551** **p=0.001**	**r=0.593** **p=0.000**	**r=0.540** **p=0.001**	**r=0.629** **p=0.000**	**r=0.406** **p=0.019**	**r=0.430** **p=0.012**	**r=0.482** **p=0.004**	**r=0.512** **p=0.002**
Dominant knee extension peak torque $(60^0.S^{-1})$	r=0.007 p=0.971	_	**r=0.388** **p=0.025**	**r=0.551** **p=0.001**	_	r=0.736 p=0.000	r=0.747 p=0.000	r=0.670 p=0.000	r=0.578 p=0.000	r=0.645 p=0.000	r=0.588 p=0.000	r=0.573 p=0.000
Dominant knee extension peak torque $(180^0.S^{-1})$	r=0.032 p=0.861	_	**r=0.465** **p=0.006**	**r=0.593** **p=0.000**	r=0.736 p=0.000	_	r=0.593 p=0.000	r=0.604 p=0.000	r=0.530 p=0.002	r=0.728 p=0.000	r=0.422 p=0.014	r=0.429 p=0.013
Dominant knee flexion peak torque $(60^0.S^{-1})$	r=0.080 p=0.659	_	**r=0.403** **p=0.020**	**r=0.540** **p=0.001**	r=0.747 p=0.000	r=0.593 p=0.000	_	r=0.764 p=0.000	r=0.666 p=0.000	r=0.609 p=0.000	r=0.902 p=0.000	r=0.687 p=0.000
Dominant knee flexion peak torque $(180^0.S^{-1})$	r=0.080 p=0.657	_	**r=0.449** **p=0.009**	**r=0.629** **p=0.000**	r=0.670 p=0.000	r=0.604 p=0.000	r=0.764 p=0.000	_	r=0.521 p=0.002	r=0.536 p=0.001	r=0.627 p=0.000	r=0.642 p=0.000
Non-dominant knee extension peak torque $(60^0.S^{-1})$	_	r=0.069 p=0.704	r=0.205 p=0.252	**r=0.406** **p=0.019**	r=0.578 p=0.000	r=0.530 p=0.002	r=0.666 p=0.000	r=0.521 p=0.002	_	r=0.738 p=0.000	r=0.654 p=0.000	r=0.477 p=0.005
Non-dominant knee extension peak torque $(180^0.S^{-1})$	_	r=0.015 p=0.934	**r=0.351** **p=0.045**	**r=0.430** **p=0.012**	r=0.645 p=0.000	r=0.728 p=0.000	r=0.609 p=0.000	r=0.536 p=0.001	r=0.738 p=0.000	_	r=0.440 p=0.010	r=0.548 p=0.001
Non-dominant knee flexion peak torque $(60^0.S^{-1})$	_	r=0.263 p=0.139	r=0.256 p=0.150	**r=0.482** **p=0.004**	r=0.588 p=0.000	r=0.422 p=0.014	r=0.902 p=0.000	r=0.627 p=0.000	r=0.654 p=0.000	r=0.440 p=0.010	_	r=0.755 p=0.000
Non-dominant knee flexion Peak torque $(180^0.S^{-1})$	_	**r=0.419** **p=0.015**	r=0.247 p=0.165	**r=0.512** **p=0.002**	r=0.573 p=0.000	r=0.429 p=0.013	r=0.687 p=0.000	r=0.642 p=0.000	r=0.477 p=0.005	r=0.548 p=0.001	r=0.755 p=0.000	_

Person correlations were performed to explore the relationships between measured parameters. Bold numbers* indicates statistically significant. $p<0.05$ was considered as statistically significant.
Abbreviations: SOS: quantitative ultrasound measurements of bone speed of sound.

Discussion

One of the notable findings in the present study was that there were statistically significant relationships between lower limb quantitative ultrasound measurement of bone speed of sound, which can reflect bone mineral density, and muscular strength in both Malay females and males. These study findings supported the results from Christine *et al.* (1990), who reported that muscular strength is an independent predictor of bone mineral density. Recently, Lee *et al* (2014) also mentioned that muscular strength is associated with BMD of hip in healthy elderly women.

Previous studies have been carried out to investigate the association between BMD and muscle strength in order to prevent bone loss through enhancing muscle strength. Hyakutake *et al.* (1994) found that higher BMD might be a function of greater muscle strength. Moreover, Ahedi *et al.* (2014) and Sinaki *et al.* (1996) have shown that greater muscle strength is related to the greater bone mass. Wulff *et al.* (2012) reported that trunk flexion peak torque was a predictor of total body and femur BMD in triathletes and supported the muscle force was an important osteogenic factor. Our present findings of close relationship between bone speed of sound and muscular strength have confirmed the positive findings of the above mentioned previous studies.

Exercise training can elicit effects on strengthening bones. Duncan *et al*. (2002) reported that running and weight-bearing exercise were related to higher BMD than swimming and cycling, and knee extension strength was correlated with BMD in adolescent females. Similarly, Rubin and Lanyon (1984) also mentioned that resistive training can increase bone health, muscular strength and muscle mass with high stress. In the present study, physically non-active but not active young Malay females and males were recruited. Nevertheless, we still observed the close relationships between bone health status reflected by tibia bone speed of sound values (Drake et al., 2002; Van den Bergh et al., 2000) and muscular strength reflected by knee muscular peak torque values.

In this study, muscular strength and power were carried out by BIODEX isokinetic dynamometer. There was a moderate positive correlation between non-dominant tibial SOS and muscular extension peak torque (PT) at $60^0.s^{-1}$ and $180^0.s^{-1}$, as well as muscular flexion PT at $180^0.s^{-1}$, not at $60^0.s^{-1}$. Due to the high cost of BMD measurement by DEXA, quantitative ultrasound is widely used to assess bone health status in different research fields, in which bone speed of sound (SOS) can reflect BMD. The close relationships between bone health status and muscular peak torque, an indicator of muscular strength in female athletes and non-active females was also reported by Sandstrom *et al.* (2000). They reported that a significant positive correlation was found between BMD of femoral neck and hamstrings muscular peak torque at $225^0.s^{-1}$ in 14 female ice hockey players, and BMD of spine neck correlated to hamstrings muscular peak torque at $90^0.s^{-1}$ and $225^0.s^{-1}$ in the 14 inactive females.

There were statistically moderate positive correlations between muscular peak torque (strength), anaerobic mean power and peak power in males in the present study. Similarly, Brown *et al.* (1994) also mentioned that muscular extension and flexion peak torque at $180^0.s^{-1}$ were correlated with anaerobic mean power and peak power measured via Wingate test. In another study by Smith (1978), statistically significant correlation between anaerobic mean power measured via Wingate test and isokinetic peak torque at $180^0.s^{-1}$ for knee flexion and extension was also reported. The present and those two previous studies imply that isokinetic peak torque measured by isokinetic dynamometer was closely related to muscular anaerobic mean power and peak power measured by Wingate anaerobic test. Additionally, muscular strength was closely related to anaerobic power.

Another notable finding of the present study was that there was no close relationship between bone measurement and Wingate anaerobic capacities i.e. mean power and peak power in non-active Malays. The measurement of anaerobic capacity, i.e. peak power and mean power by Wingate test was initially presented by Ayalon *et al.* (1974). The present finding was not similar to a study by Witzke and Snow (1999) who showed that leg power assessed by Wingate test was correlated with BMD at all sites except the lumbar spine. Additionally, Haydari *et al.* (2010) also reported that there was a positive relationship between femoral neck and trochanter BMD and anaerobic power in elite jumpers ($r=0.446$, $P<0.05$). To our knowledge, the present study was the first study to assess the relationship between bone speed of sound and anaerobic capacities in non-active Malay university students who exercised less than 2 times per week, this may cause discrepancy between the findings of Haydari *et al.* (2010) with elite jumpers and the present study with non-athletes. Furthermore, differences in ethnicity may have caused the inconsistent results of the present study compared to Witzke and Snow (1999) and Haydari et al. (2010).

Conclusions

To our knowledge, this is the first study to determine the correlation between bone health status, muscle strength and Wingate anaerobic capacities in Malay females and males university students. Most researchers indicated that the impact or load of the muscle contraction on bone may cause an advantageous effect on bone mineral density. Our present findings show that participants' lower limbs bone health status is related to muscular strength. However, bone health status is not related to anaerobic capacities in non-active young Malay females and males university students. Therefore, further study to investigate the association between bone health status, muscular performance, genetic and exercise habits of Malays is warranted.

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Author Disclosures
The authors declare that there is no conflict of interests regarding the publication of this paper.

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